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Newfoundland and Labrador Region

Canadian Science Advisory Secretariat
Science Advisory Report 2017/051

STOCK ASSESSMENT OF NAFO SUBDIVISION 3PS COD

Image: Gadus morhua.

Figure 1: Subdivision 3Ps management area and economic zone around the French islands of St. Pierre et Miquelon (SPM) (dashed line).

Context:

In the Northwest Atlantic, cod are distributed from Greenland to Cape Hatteras and are managed as 12 stocks. The Northwest Atlantic Fisheries Organization (NAFO) Subdivision (Subdiv.) 3Ps stock off southern Newfoundland extends from Cape St. Mary's to just west of Burgeo Bank, and over St. Pierre Bank and most of Green Bank (Fig. 1).

The distribution of 3Ps cod does not conform well to management boundaries and the stock is considered a complex mixture of inshore and offshore sub-components. These may include fish that move seasonally between adjacent areas as well as fish that migrate seasonally between inshore and offshore. The extent to which the different components contribute to the fisheries is not fully understood.

Female cod from this stock have generally matured at younger ages since the mid-1990s. About 50% of the females are mature by age 5 (~47 cm) in these more recent cohorts, compared to only about 10% at age 5 (~55 cm) among cohorts present in the 1970s-1980s.

Catches from this stock have supported an inshore fixed gear fishery for centuries and are of vital importance to the area. Fish are caught offshore by mobile and fixed gear, and inshore by fixed gear only. Spanish and other non-Canadian fleets heavily exploited the stock in the 1960s and early 1970s. French catches increased in the offshore throughout the 1980s. A moratorium on fishing initiated in August, 1993 ended in 1997 with a quota set at 10,000 t. Beginning in 2000, the management year was changed to begin on 1 April. The Total Allowable Catch (TAC) for the 2016/17 management year was set at 13,043 t. Under the terms of a 1994 Canada-France agreement, Canada holds 84.4% of the TAC, while the remainder (15.6%) is held by France (St. Pierre et Miquelon).

The present assessment is the result of a request for science advice from the Fisheries Management Branch (Newfoundland and Labrador [NL] Region). The main objectives were to evaluate the status of the stock and to provide scientific advice concerning conservation outcomes related to various fishery management options.

Participants included Fisheries and Oceans Canada (DFO) scientists and fisheries managers, a

scientist from the French Research Institute for Exploitation of the Sea (IFREMER; France), academia, fishing industry representatives from Canada, and a representative from the province of NL.

This Science Advisory Report is from the October 17-18, 2017 Assessment of NAFO Subdivision 3Ps Atlantic Cod. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Consistent with recent assessments, a cohort model (SURBA) based on the spring Fisheries and Oceans Canada (DFO) survey was used to infer overall stock trends.
- The 2017 spawning stock biomass (SSB) is estimated to be in the Cautious Zone (54% above B_{lim}) as defined by the DFO Precautionary Approach (PA) Framework. The probability that the stock is in the critical zone is 0.03.
- SSB decreased from 2012, but showed an increase in 2017. However, SSB is concentrated (75% of SSB) in ages 5 and 6, with few older (ages 7+) fish in the population.
- Recruitment has generally been at or above the time-series average since 2005, with particularly strong cohorts produced in 2006 and 2011.
- Estimated total mortality decreased slightly in 2016, but remains high. Over 2014-16, total mortality averaged 0.7 (50% survival per year), however the relative contributions of natural and fishing mortality to total mortality are unknown.
- Projection of the stock to 2020 was conducted assuming mortality rates will be within ± 20% of current values (2014 to 2016 average). Projected SSB shows a continuous decline to 2020 in most cases, with the decrease ranging from 23 to 58% (2017 to 2020). The risk of being below B_{lim} by 2019 ranges from 0.09 and 0.73, and by 2020 from 0.25 to 0.94.
- Ecosystem signals observed in Subdiv. 3Ps in recent years indicate that structural changes are occurring, and overall ecosystem productivity may be low. Although the full impacts of these changes on cod itself are not fully known, they imply that at least some aspects of cod productivity may be impaired.

INTRODUCTION

Oceanography and Ecosystem Overview

Oceanographic conditions in the Subdivision (Subdiv.) 3Ps area are influenced by several factors including local atmospheric climate conditions, advection by the Labrador Current from the east and the warmer and saltier Gulf Stream waters from the south as well as the complex bottom topography in the region. Near bottom temperatures, while showing significant variability from one year to the next, have experienced a general warming trend for over two decades.

Compared with the period 1998 to 2017, the spring phytoplankton bloom was observed later, of shorter duration, and reduced in magnitude during 2015 to 2017. During this recent period, zooplankton biomass was also the lowest in the time-series.

The overall biomass of the fish community in 3Ps has been relatively stable since the mid-1990s, whereas the overall abundance increased due mainly to an increase in small planktivorous (plankton-eating) fishes (e.g. sandlance). However, both overall biomass and abundance were reduced over 2015 to 2017. For piscivorous (mainly fish-eating) fish, biomass has been declining in Subdiv. 3Ps since the early 2010s although the biomass of Silver Hake (*Merluccius bilinearis*) increased during that period, and in 2017 surpassed that of the

historically dominant Atlantic Cod. The increase in biomass of Silver Hake, considered a warm-water species, may be linked to the warming trend in this ecosystem. Across all fish functional groups, average fish size declined in the mid to late-2000s and has remained at lower levels.

Cod in 3Ps have a highly variable diet, with the dominant prey species changing over time. In 2013-16 the diet of cod was highly dominated by Snow Crab, but in 2017 sandlance become the dominant prey item. A fish based diet is likely of higher quality than one based on invertebrates. Preliminary diet data for Silver Hake in 3Ps suggests that this species is not in direct competition with cod for food.

Overall, the ecosystem signals observed in 3Ps indicate that the structure of this ecosystem is changing, and likely experiencing lower productivity conditions. Although the full impacts of these changes on cod itself are not fully known, they imply that at least some aspects of cod productivity may be impaired.

History of the Fishery

The stock was heavily exploited in the 1960s and early 1970s by non-Canadian fleets, mainly from Spain, with catches peaking at 87,000 t in 1961 (Fig. 2).

After the extension of jurisdiction in 1977, landings increased to peak at almost 59,000 t in 1987 due to increased landings by France. Landings then decreased sharply to about 40,000 t during 1988-91 before decreasing further to 36,000 t in 1992.

A moratorium was imposed in August, 1993 and at that time 15,000 t of the 20,000 TAC had been landed. Although offshore landings fluctuated, the inshore fixed gear fishery reported landings around 20,000 t each year until the moratorium.

The fishery reopened in May, 1997 with a TAC of 10,000 t, increasing to 30,000 t by 1999. In 2000 the management year was changed to begin on 1 April. Total Allowable Catches and landings over the past decade are shown in Table 1 and are described in detail below. The TAC was set at 13,043 t for the 2016/17 management year, based on a Harvest Control Rule. In recent years, catches were approximately half of the TAC generated from the Harvest Control Rule (see Management Considerations section). Canada and France agreed to a TAC of 6500 t for the ongoing 2017/18 management year.

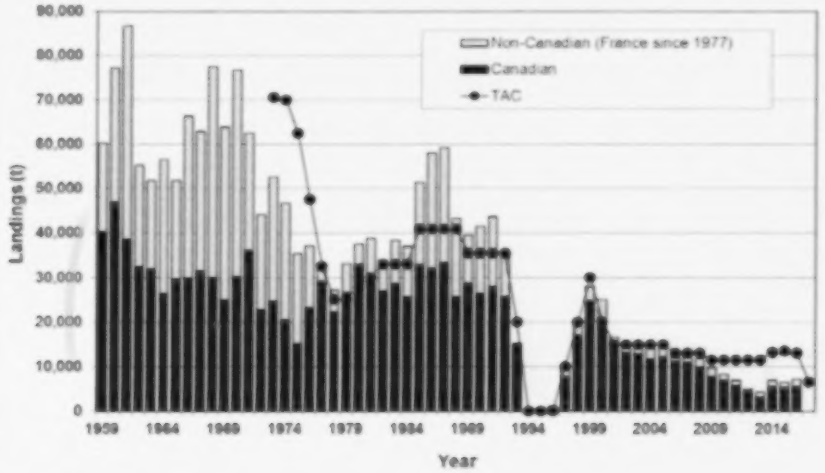

Figure 2: Reported annual landings and TACs (t) from 1959-2017. Values are based on calendar year from 1959-2000 and on management year (1 April-31 March) since then. Landings for 2017 (2017/18 season) are incomplete and not displayed.

Landings

Table 1: TAC and landings by management year (thousand metric tons).

-	08-09	09-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17[1,2]	17-18[1,2]
TAC[3]	13.0	11.5	11.5	11.5	11.5	11.5	13.225	13.49	13.043	6.5
Canada	10.6	7.5	6.6	5.2	4.0	4.6	5.8	5.9	5.2	2.4
France	2.0	1.5	1.3	1.1	0.8	1.4	1.6	0.9	1.1	0.02
Totals	12.6	9.0	7.8	6.3	4.8	6.0	7.3	6.8	6.3	2.4

[1] Provisional.
[2] Approximate landings to September 28, 2017.
[3] TAC is shared between Canada (84.4%) and France (St. Pierre et Miquelon; 15.6%).

Reported combined landings by Canada and France were substantially below the TAC from the 2009/10 season to 2016/17. During the 2016/17 season, approximately half (48%) of the 13,043 t TAC was landed. Prior to 2009/10, the TAC had been almost fully subscribed with the exception of the initial four years of TAC regulation. Industry participants have indicated multiple reasons contributing to the recent reduction in landings, including reduced cod availability and economic factors. Of the 6,282 t landed during the 2016/17 season, 5,215 t was taken by Canada (including 10 t from sentinel surveys), and 1067 t was landed by France.

Provisional data (as of September 28, 2017) indicate landings during the ongoing 2017/18 management year were 2,396 t, of which 15 t was landed by France. Although incomplete, these landings to date are comparable to those from recent years when landings approximated the current TAC of 6,500 t.

During the 2016/17 season, approximately three-quarters of the total landings were taken by fixed gears (dominated by gillnet) with the remainder taken by the otter trawl fleet.

Species Biology

Stock structure and **migration patterns** of Subdiv. 3Ps cod are complex. Cod in 3Ps mix with adjacent stocks at the margins of the stock boundary. Some offshore components of the stock migrate seasonally to inshore areas, and there are inshore components that are shoreward of the spring DFO Research Vessel (RV) trawl survey area. These features add uncertainty to the assessment of stock status. However, since 1994, additional information has been obtained from various sources, including tagging, acoustic telemetry, and the sentinel fishery. This information has provided a basis for several measures to investigate the potential impact of these factors (i.e., stock structure and migration patterns) on the assessment. Survey timing was shifted to April (beginning in 1993) and winter fishery closures in some areas have been imposed to reduce the potential for migrant non-3Ps cod being sampled by surveys and included in commercial catches. The spring DFO RV trawl survey covers most of the stock so survey trends are thought to broadly reflect stock trends.

Spawning is spatially widespread in 3Ps, occurring close to shore as well as on Burgeo Bank, St. Pierre Bank, and in the Halibut Channel. Timing of spawning is variable and extremely protracted, with spawning fish present from March until August in Placentia Bay. Detailed examination of fish collected from Halibut Channel (southern portion of 3Ps) in March and April of 2015 and 2016 suggested that spawning in this area began in April. Also, it was noted that for these fish, all females initially categorized as spent were in fact likely skipping spawning; therefore, previous estimates of spawning time may be biased and estimated to be earlier than actual spawning times.

Maturation in female cod was estimated by cohort. The proportion of female cod maturing at ages 4-6 is higher for all cohorts subsequent to the 1985 cohort. The reasons for the change toward earlier age at maturity are not fully understood but may have a genetic component that is partly a response to high levels of mortality including fishing. Males generally mature about one year younger than females but show a similar trend over time.

Growth, calculated from length-at-age in research trawl survey samples, has varied over time. For cod older than age 3 there was a general decline in length-at-age from the early 1980s to the mid-1990s. For most ages there was an increase in length-at-age from the mid-1990s through the mid-2000s, followed by a period of lower length-at-age in recent years. Length-at-age during 2013-17 was among the lowest in the time series.

Condition (or condition factor) is a measure of fish weight relative to length and is considered a proxy for energy reserves. Comparison of post-1992 condition with that observed during 1985-92 is difficult because survey timing has changed. Condition varies seasonally and tends to decline during winter and early spring. There were signs of improved fish condition during 2008-13, but condition values for 2014-17 subsequently declined and are among the lowest in the time series. Similarly, most estimates of condition from sentinel sampling in recent years are below the time-series average.

ASSESSMENT

Resource Status

Sources of Information

A cohort model (SURBA) based on abundance indices from Canadian RV trawl surveys (1972-2017) is used to infer overall stock trends (Cadigan 2010). This model can only use a single index of stock abundance. Although additional sources of information are presented (see "Other Data Sources" below), only the RV survey data was selected as the input data for the

model because it is collected with a standardized design over most of the stock area and is thought to best reflect overall trends in the stock.

Research Vessel Surveys

Canadian DFO RV bottom **trawl surveys** have been conducted in 3Ps since 1972, however, surveys from 1972-82 had poor coverage. The surveyed area was increased by 18% by the addition of strata closer to shore in 1994 and 1997. The survey was not completed in 2006.

Survey indices based on strata <550 m (<300 ftm) are presented for the expanded DFO survey area since 1997 (inshore plus offshore; denoted "All index strata") as well as for the offshore only strata ("Offshore index strata") in figures 3 and 4. Any near-shore aggregations in April would not be measured by the DFO RV survey. The majority of the area shoreward of the DFO RV survey lies within inner and western Placentia Bay. There is no recent evidence that a large fraction of the stock is shoreward of the DFO RV survey in April.

The **biomass index** from the offshore strata is variable but exhibits a downward trend from the mid-1980s to the early 1990s (Fig. 3). Values for most of the post-moratorium period from 1997 to 2004 were higher than those of the early 1990s, but not as high as those of the 1980s. Biomass estimates in recent years have generally been low, with eight of the last eleven years being below the 1997-2017 average. Survey catches in 2017 were generally low, with higher catches only in the Halibut Channel, on Burgeo Bank and in Fortune Bay, where one unusually high catch was observed. Survey biomass from the expanded index ("All index strata") shows similar trends to the offshore-only index.

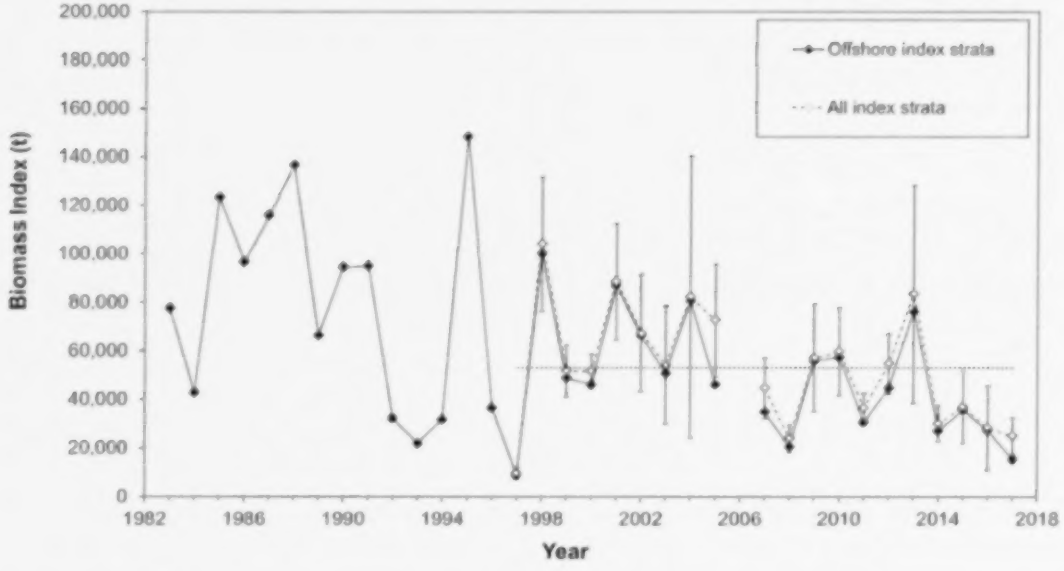

Figure 3: RV survey biomass indices (t).Error bars are ± one standard deviation for combined survey index–dashed line is the time series average of the combined survey index.

The offshore DFO RV abundance index is variable, but values during the 1990s were generally lower than those from the 1980s (Fig. 4). Abundance was low during the 2000s but somewhat higher over 2010-15 with four of the six years being at or above average. In particular, the 2013 estimate was very high with a high measure of uncertainty. In 2017, abundance levels were below the 1997-2017 average, similar to those observed in the 2000s.

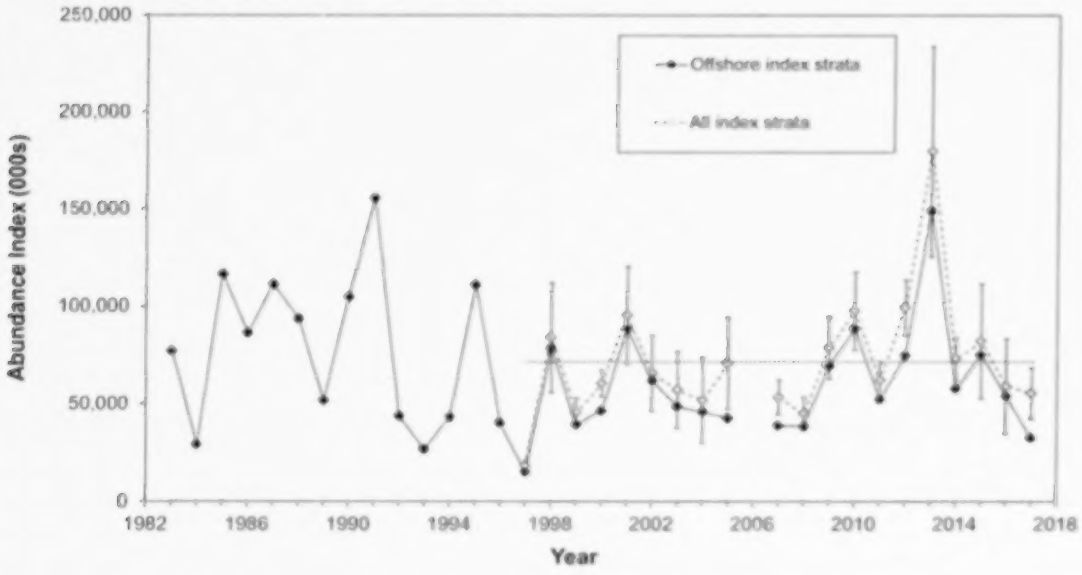

Figure 4: Research vessel survey abundance indices. Error bars are ± one standard deviation for combined survey, dashed line is average of combined survey index.

Age Composition

Catches during the 2017 RV survey consisted mainly of cod aged 2-6 (85% of abundance index). Indications are that the 2011 (age 6 in 2017) and 2012 (age 5 in 2017) year classes are strong. The abundance of cod older than age 6 is relatively low.

Reference Points

The Limit Reference Point (LRP) for this stock is $B_{Recovery}$, the lowest observed spawning stock biomass (SSB) from which there has been a sustained recovery. The 1994 value of SSB based on the SURBA analysis has been identified as the LRP. The Upper Stock Reference (USR) has been defined (by fisheries managers) as two times the LRP. Mortality reference points have not been identified for this stock.

Spawning Biomass

Cohort analyses of the RV data indicated that SSB declined by 58% over 2004-09 (Fig. 5). Median SSB was estimated to be below the LRP in 2009. SSB increased considerably over 2009-12 but has since declined. The 2017 SSB is estimated to be in the Cautious Zone (54% above B_{lim}) as defined by the DFO Precautionary Approach (PA) Framework. Estimates of the uncertainty of the 2017 SSB indicate that the probability that the stock is in the critical zone is 0.03. Very low numbers of older (ages 7+) fish in the population combined with the presence of the strong 2011 and 2012 year classes resulted in nearly three quarters of the 2017 SSB being made up of 5-6 year old fish. This is an enormous reliance on young spawners and may be a concern given that younger fish produce fewer and smaller eggs/larvae that may have reduced survival. Young fish also spawn over a narrower time frame which decreases the probability of overlap between larval emergence and peak plankton abundance and can result in reduced survival.

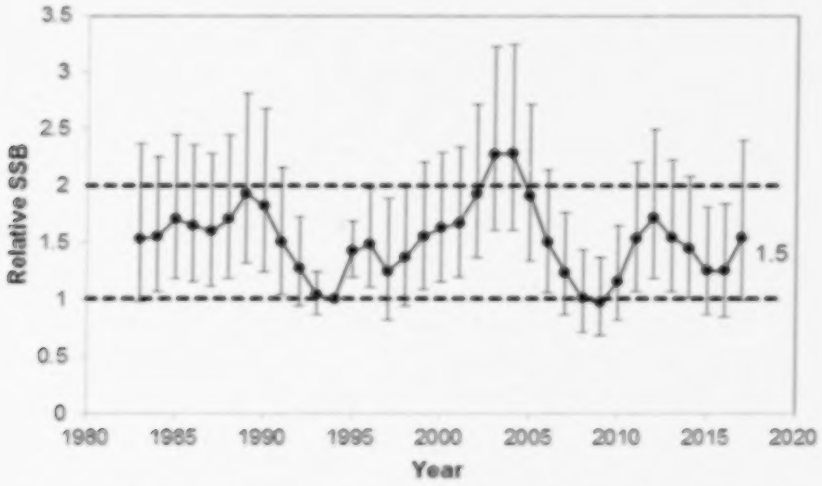

Figure 5: Cohort analysis estimates of SSB, relative to the B_{lim} value (median estimate with 95% confidence interval). The lower dashed line at one (reference level) represents the SSB Limit Reference Point and the upper horizontal dashed line at two represents the Upper Stock Reference (i.e., 2 x LRP). These reference points represent the boundaries between the zones of DFO's precautionary approach framework, as indicated on the right axis. Text label indicates the current SSB relative to the LRP.

Mortality Rates

Total mortality rates reflect mortality due to all causes, including fishing. Generally, estimated total mortality for ages 5-10 from the cohort model (Fig. 6) has been increasing since 1997, but it decreased slightly in 2016. This decline was due to the large number of younger (age 5-6) fish in 2017, which have lower mortality rates compared to older individuals. Over 2014-16, the total mortality rate averaged 0.70 (equivalent to 50% per year). This is very high considering that landings have been about half of the TACs over this time period. The current truncated age structure indicates that fish in this population are not surviving to older ages and the extent to which this might be related to recent low nutritional condition and/or early age at first maturity is not certain.

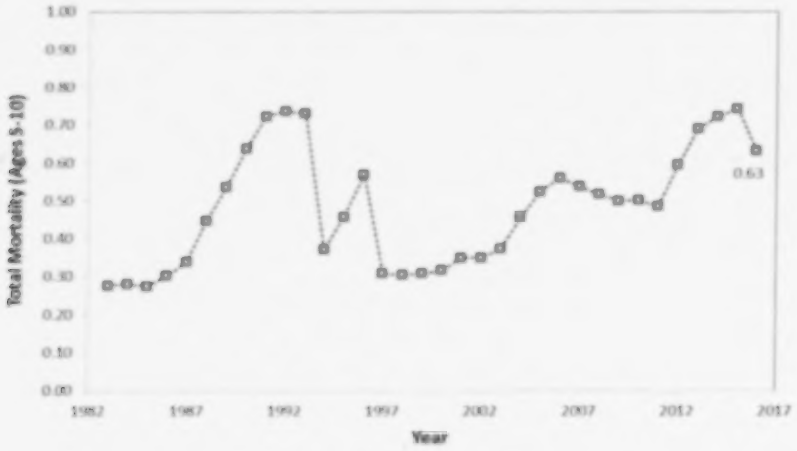

Figure 6: Cohort analysis estimates of population weighted average annual mortality (ages 5-10). Text label indicates the estimated total mortality for 2016.

Recruitment

Recruitment (Fig. 7) has improved over the last decade with most cohorts at or above the time series (1983-2016) average. Indications are that the 2011 and 2012 cohorts are among the strongest in the time series. However, even these strong cohorts are expected to decline rapidly in coming years if total mortality rates remain at recent high levels.

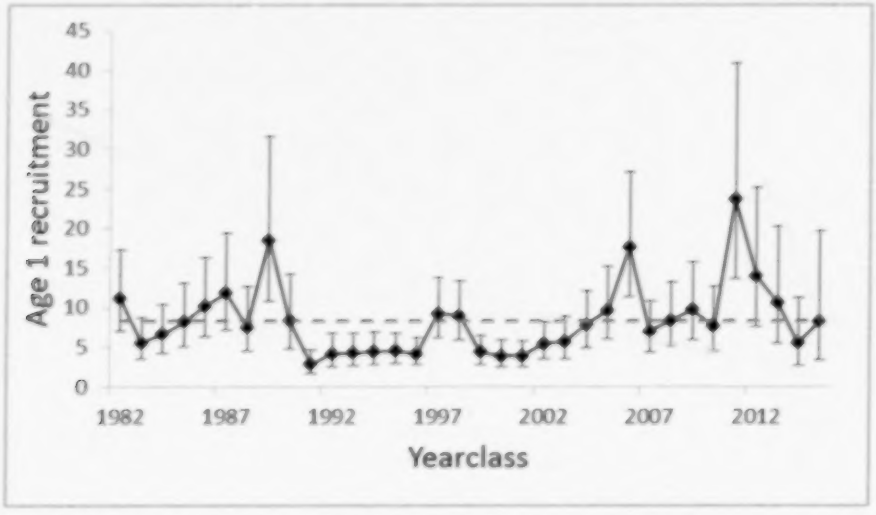

Figure 7: Estimated relative year-class strength from cohort model (median estimate with 95% confidence intervals). The dashed horizontal line is the time-series median.

Projection

Projection of the stock to 2020 was conducted assuming mortality rates will be within ± 20% of current values (2014-16 average). Projected SSB shows a continuous decline to 2020 in most

cases, with the decrease ranging from 23 to 58% (2017 to 2020). The risk of being below B_{lim} by 2019 ranges from 0.09 and 0.73, and by 2020 from 0.25 to 0.94 (Table 2).

Table 2: Risk of projected SSB being below B_{lim} under five scenarios of total mortality (Z at status quo, ±10% status quo and ±20% status quo) over 2018- 2020. Status quo Z was estimated as the geometric mean of the last three year.

Year	Mortality (Z) scenario	Relative SSB (median with 95% CI)	P(SSB<B_{lim})
2017	Status quo	1.54 (0.99-2.40)	0.03
2018	-20%	1.57 (1.00-2.45)	0.02
	-10%	1.47 (0.94-2.31)	0.04
	Status quo	1.39 (0.88-2.18)	0.08
	+10%	1.30 (0.83-2.06)	0.13
	+20%	1.23 (0.78-1.94)	0.19
2019	-20%	1.36 (0.86-2.15)	0.09
	-10%	1.21 (0.76-1.93)	0.21
	Status quo	1.08 (0.67-1.73)	0.38
	+10%	0.96 (0.60-1.56)	0.56
	+20%	0.86 (0.53-1.41)	0.73
2020	-20%	1.18 (0.73-1.91)	0.25
	-10%	1.01 (0.62-1.66)	0.48
	Status quo	0.87 (0.52-1.45)	0.71
	+10%	0.75 (0.44-1.27)	0.86
	+20%	0.65 (0.38-1.12)	0.94

Harvest Control Rule

The Conservation Plan and Rebuilding Strategy (CPRS) adopted by Canada to guide management decisions includes a Harvest Control Rule (HCR) for calculating the TAC based on recent stock trends and current stock status. The rule calculates a proposed TAC for the coming year by adjusting the current year TAC based on the trend in SSB.

The value calculated by the HCR was adopted as the TAC for this stock for the 2016/17 season. Catches of approximately half these values did not promoted recovery of the stock toward the

healthy zone. Use of the CPRS was suspended for the 2017/18 season and there was no request to provide advice based on its calculation for the 2018/19 season.

Other Data Sources

Other sources of information were considered in the assessment to provide perspectives on stock status in addition to the DFO survey indices. These sources of information include data from the Sentinel survey (1995-2016), science logbooks for vessels less than 35 feet (1997-2016), logbooks from vessels greater than 35 feet (1998-2016) and observer sampling. Results of a 2017 Fish, Food and Allied Workers Union (FFAW) telephone survey of inshore Canadian fish harvesters and exploitation (harvest) rates estimated from tagging experiments in Placentia Bay (and more recently Fortune Bay), were also available. Any differences in trends between these additional data sources and the DFO survey are difficult to reconcile but attributed to differences in survey/project design, seasonal changes in stock distribution, differing selectivity of various gear types, or the degree to which the various data sources track only certain subareas/ components versus the entire distribution of the stock.

Sentinel survey

Fixed gear sentinel surveys have been conducted at sites along the south coast of Newfoundland from St. Bride's to Burgeo from 1995 through 2017. Gillnet results come mostly from sites in Placentia Bay whereas line-trawl results come mostly from sites west of the Burin Peninsula. The sentinel survey for 2017 is still ongoing; hence, the data for 2017 are incomplete and were not included in the modeling reported below.

The sentinel survey data were standardized to remove site and seasonal effects to produce annual indices of the total and age-specific catch rates (Fig. 8).

The standardized total annual catch rate for gillnets was highest from 1995-97, but progressively lower in 1998 and 1999, and remained quite low from 2000 to 2016 (Fig. 8, upper panel). The line-trawl catch rates were high in 1995 with a steady decline to 1999, but were subsequently fairly constant through 2009 (Fig. 8, lower panel). More recent (2013-16) values are the lowest in the time-series.

The standardized age-specific catch rates for sentinel gillnets and line-trawls show similar trends with the relatively strong 1989 and 1990 year-classes being replaced by subsequent weaker year-classes resulting in an overall decline in catch rates. Although the magnitude of the sentinel catch rates has been generally constant for more than a decade, the 1997 and 1998 year-classes were consistently evident in both age disaggregated sentinel indices. In addition, the 2004 year-class appears to be well-represented only within line-trawl results. The relative strength of more recent year-classes in the sentinel results is less clear, but generally indicates that they are relatively weak. Comparison of sentinel catch rates and the RV index at times show inconsistent age compositions; these differences are not fully understood. As an example, the 2006 year-class ranks above average in the RV survey, but does not appear particularly strong in either sentinel index even though fish in this year-class are now available to these gears. The 2011 year class, which appears as the strongest in the RV survey, appears prominently in the 2016 sentinel survey. The 2012 year class also appeared strong in the RV survey but it is not yet of age to be fully selected by either of the gears in the 2016 sentinel survey.

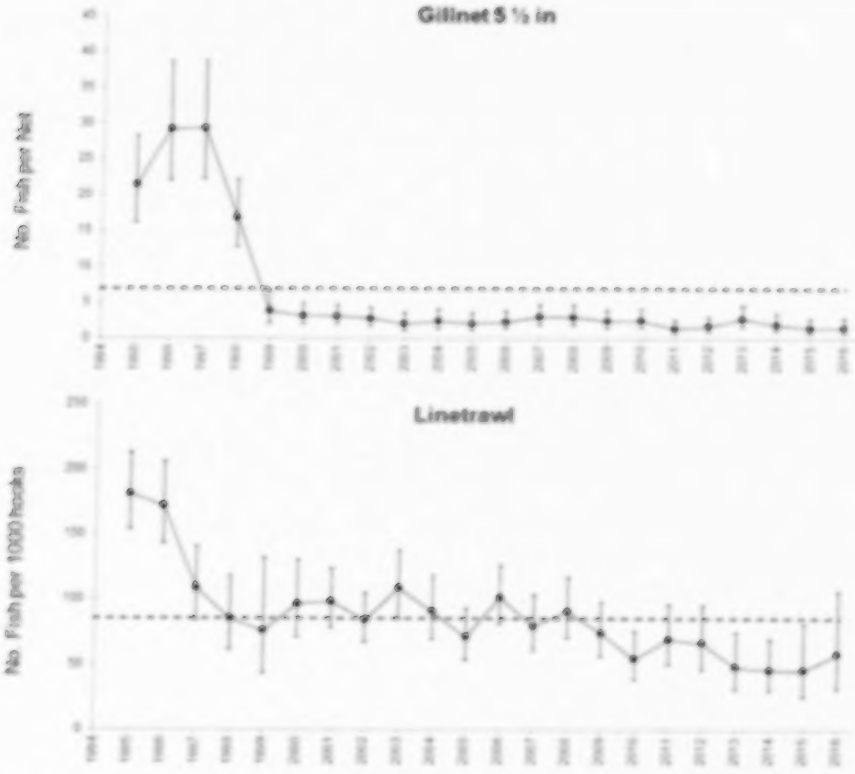

Figure 8. Standardized sentinel catch rates for gillnets (upper panel) and line-trawls (lower panel). Error bars are 95% confidence intervals; dashed lines represent the time-series average.

Logbooks

There is considerable uncertainty in the interpretation of fishery catch rate data. These data may be more reflective of changes in fishery performance or the nature of the fishery than changes in population size.

Logbooks for < 35' Vessels

Standardized annual catch rates from science logbooks (< 35' sector) for Canadian vessels fishing gillnets show a declining trend over 1998-2000, but have subsequently been fairly constant (Fig. 9, upper panel) near the time series average. Note that the 2015 data from this logbook series were not available at the time of the current assessment. Line-trawl catch rates show a much different pattern with a greater degree of variation (Fig. 9, lower panel). After peaking in 2006, line-trawl catch rates generally declined to near the time-series average in 2009 and remained at similar levels up to 2014. Catch rates for line trawls during 2016 were the lowest in the time series, but this result is based on very low reporting rates (13 logbooks) with no logbooks returned from many areas. The commercial catch rate index is based on weight of fish caught whereas the sentinel index is based on numbers. As with the sentinel results, there is contrast between the two gear-types in current catch rates relative to the time-series average. For gillnets, current CPUE is at the level of the series average, whereas current line-trawl CPUE is 57% below average.

The percentage of the catch from the < 35' sector that is accounted for in the standardized logbook indices has declined over time and now represents less than 15% of the catch as compared to approximately 70% at the start of the time series in 1997. This likely affects the quality, and comparability, of this index over time, such that it is unclear if the CPUE trends reflect the fishery as a whole.

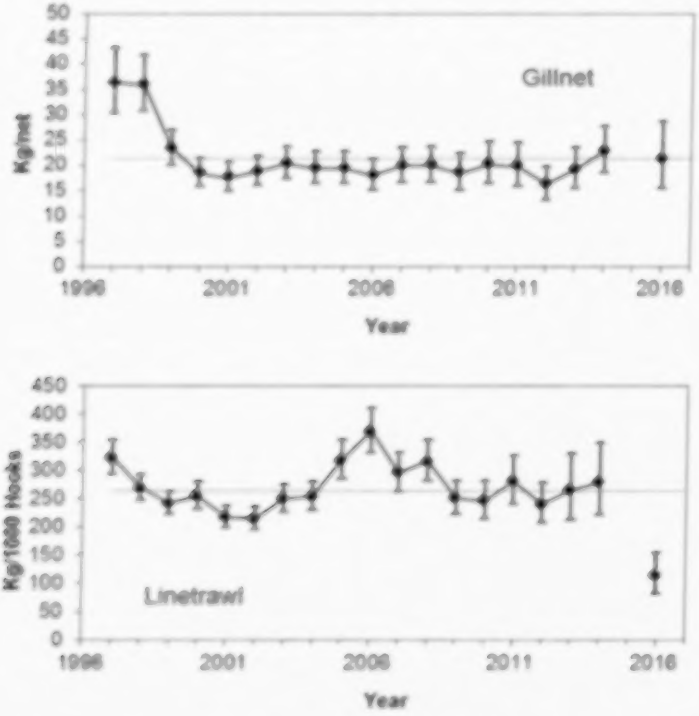

Figure 9: Standardized catch rates for gillnets (upper panel) and line-trawls (lower panel) derived from logbook data for vessels less than 35'. Data were unavailable for 2015 during the 2017 assessment. Error bars are 95% confidence intervals; dashed lines represent the time-series average.

Logbooks for > 35' Vessels

Catch rates for gillnets from vessels > 35' were standardized to account for spatial and seasonal effects. For these vessels, standardized annual catch rates (Fig. 10, upper panel) were higher in magnitude than those from vessels less than 35 feet (Fig. 9), but the general pattern was similar. Both time series showed an initial decline over 1998 to 2000 followed by fairly constant catch rates to 2016. Over the last decade, approximately two thirds of the reported landings from vessels > 35' were accounted for by the standardized gillnet index, which is slightly higher than earlier in the series when less than 50% coverage occurred frequently. Further analyses are required to develop a standardized catch rate index for line trawls fished by vessels > 35'. For the otter trawl fleet, catch rates were standardized to remove spatial, seasonal, and vessel size (greater or less than 100 feet) effects. Standardized annual catch rates for otter trawlers generally declined from 1999 to 2016 with high values during 2006 (Fig. 10, lower panel) attributed to atypically high fishing effort in 3Psh where catch rates are much higher than other areas. The percentage of the otter trawl catch that is accounted for in the standardized index was variable over time (27-94%) but has been 80% or higher since 2010. During this period, the

otter trawl fleet was small and logbook data was available from less than ten vessels annually. The long term decline in catch rates by otter trawlers is broadly consistent with the declining trend in biomass indices from the RV survey. However, otter trawl effort is variable with respect to timing (little or no autumn tows during some years) and is highly concentrated relative to RV survey coverage.

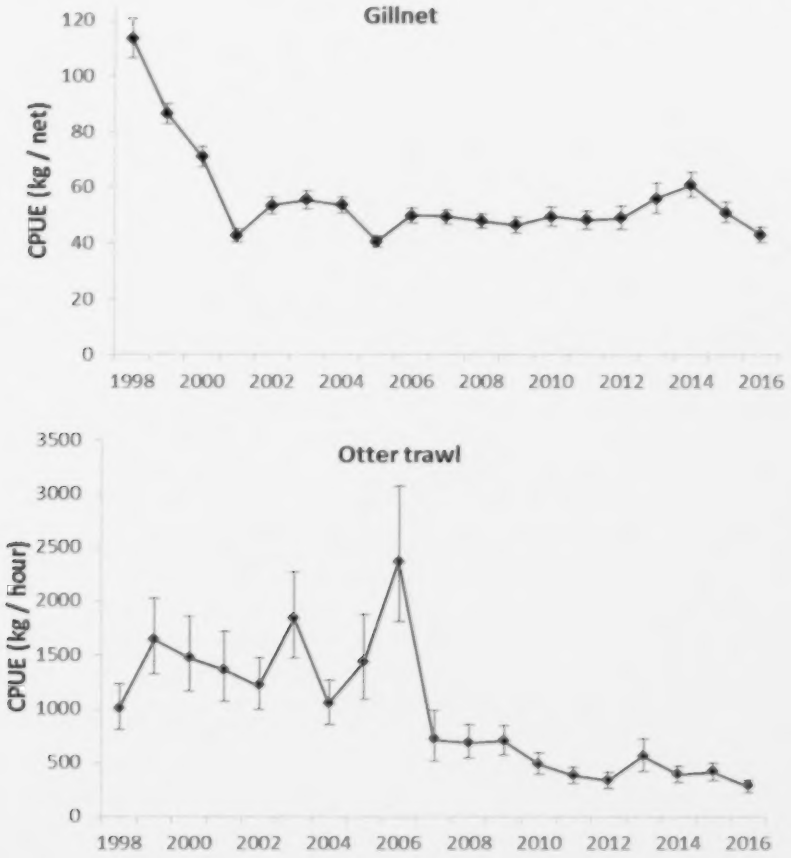

Figure 10: Standardized catch rates for gillnets (upper panel) and otter trawls (lower panel) derived from logbook data for vessels greater than 35'. Error bars are 95% confidence intervals.

Observer sampling

Information collected at sea by observers on Canadian vessels fishing for cod (1997-2016) were reviewed for the potential to create a standardized catch rate index from these data in future assessments. Data exploration indicated substantial variations in observer coverage over time and among unit areas, as well as by fleet sector. Although the proportion of the landings observed is low (< 2%) for most years and areas, data from gillnets generally support that the catch rates during 2016 were among the lowest in the times series (1997 to 2016). Data on line trawl effort was not available in time for the assessment. There was insufficient data from otter trawl sampling to develop a standardized index.

Tagging

The geographical coverage of tagging since 2007 has been limited to areas of Fortune Bay and Placentia Bay, which causes some uncertainty as to how results from these inshore areas relate to the stock as a whole. The number of cod tagged has varied annually and by area with tagging conducted annually in 3Psc (Placentia Bay) during 2007 to 2015, in 3Psb (Fortune Bay) during 2012 to 2016 (plus 2007) and in 3Psa only during 2013. Although exploitation rates based on tagging of cod in these inshore areas may not be applicable to other areas, or to the stock as a whole, these inshore regions account for a significant portion (~ 50%) of the overall annual landings from the stock.

Exploitation (harvest) rates for 2016 were estimated adjusting for tag reporting rates (~ 67% during 2016) based on high-reward tagging and a range of assumed values for the annual rate of natural mortality (M=0.2 or 0.4). At M=0.2, in 2016, the harvest rates ranged from 12% to 19% (F=0.13 to 0.21) among cod 50-85 cm at release tagged in Placentia Bay and Fortune Bay. These values would be approximately double if the entire quota had been taken as most of the unharvested TAC was available to the inshore sector. Recent tagging suggests exploitation of 3Ps cod in neighbouring stock areas (Divs. 3KL) is minimal and not a major issue for management. No new data are available to investigate mixing in the western portion of the stock area (3Psa/d). Overall, post-moratorium inshore tagging studies have generally revealed extensive movement of cod between Placentia Bay (3Psc) and Fortune Bay (3Psb), but limited movement from inshore to offshore. In contrast, many cod tagged offshore in Halibut Channel (3Psh) have shown extensive seasonal movement shoreward, particularly into Placentia Bay during summer.

FFAW Telephone Survey

Canadian fixed-gear fish harvesters' perspectives on the 2016 and ongoing 2017 fisheries were compiled based on the results of the telephone survey conducted by the FFAW. Results are based on the responses of 56 active harvesters. Harvesters from the eastern region (St. Bride's to Point May) reported catch rates were better in 2017 than in 2016. A similar shift was not reported by those fishing between Fortune and Burgeo Bank.

Surveyed harvesters reported low levels of capelin and squid in 3Ps during the 2016 season, with sandlance and crab being most commonly reported in cod stomachs in 2016. However, reports from the ongoing 2017 fishing season indicate capelin, herring and squid increased in abundance, particularly in the bays. Additionally, harvesters reported a shift in the distribution of cod, with higher catch rates further inshore than has been the case in recent years.

Sources of Uncertainty

Although the RV survey of Subdiv. 3Ps includes coverage of 45 index strata, the majority of the survey indices for cod are typically influenced by catches from only a small number of those strata. In some years the high estimates in some of these strata are a result of a single large survey tow. For example, in two of the last three years, a large survey tow on Burgeo Bank has had a major influence on survey indices (e.g. 60% of the biomass index in 2016 resulted from a single survey tow in stratum 309). The presence of single large survey tows results in increased uncertainty in the survey data which is not accounted for in the cohort analysis.

Survey indices are at times influenced by "year-effects", an atypical survey result that can be caused by a number of factors (e.g., environmental conditions, movement, degree of aggregation, etc.) which may be unrelated to absolute stock size. There are strong indications that the 2013 survey may have been influenced by a year effect that resulted in a large spike in the survey indices for that year. The 2013 RV survey estimated that the abundance of multiple

cohorts increased compared to observations of these same cohorts at one age younger in 2012. Since the number of fish in a cohort cannot increase after it is fully recruited to the survey gear (without immigration), such results are usually considered clear evidence for a year effect. Year effects in the survey data have the potential to mask trends in the data for several years and contribute to retrospective patterns.

Recent assessments of 3Ps cod have been subject to revisions of estimates from previous years with the addition of a new year's survey data. Using the most updated data in 2017, only minor revisions were observed in previous year estimates of SSB, total mortality, and recruitment at age one. These revisions are not uncommon in cohort models, which use annual information to predict the abundance of multiple cohorts.

Burgeo Bank is a known seasonal mixing area for cod from 3Ps and those from the Northern Gulf of St. Lawrence. The DFO RV survey was moved to April in 1993 to minimize the impact of migratory Northern Gulf fish on the assessment of 3Ps cod. However, at least one published study suggests that a non-trivial portion of fish in the Burgeo Bank area in April is of Northern Gulf origin (Méthot et al. 2005). The potential presence of non-3Ps fish in this area at the time of the survey combined with the fact that a large portion of the survey indices have come from the Burgeo Bank area in recent years suggests the potential for overestimation of survey results.

The level of total removals is uncertain. It is likely that landings have been biased both upwards (e.g., due to misreporting of catch by area and/or species) and downwards (e.g., due to discarding). In addition, commercial catch accounting procedures pre- and post-moratorium are radically different, with current measures likely to provide improved estimates of removals. Estimates of recreational fishery landings have not been available since 2006. In assessing stock status, it would be useful to better understand the accuracy of total removals. Given these uncertainties and the variability in the reliability of removals estimates, the decision was previously made to assess this stock based on a cohort model that incorporates only RV catch information (i.e., no commercial catch data). Assessment models do exist that are capable of handling uncertainty in the catch estimates but a full evaluation of these or any other model formulations would require a framework meeting.

The relative efficiency of the survey trawl at capturing different age groups is uncertain. Differing patterns of catchability were explored in a previous assessment and yielded a similar outcome in terms of current status relative to the LRP. If the catchabilities differ from the assumed values, stock dynamics may differ from the results presented above.

CONCLUSIONS AND ADVICE

- Consistent with recent assessments, a cohort model (SURBA) based on the spring DFO survey was used to infer overall stock trends.
- The 2017 SSB is estimated to be in the Cautious Zone (54% above B_{lim}) as defined by the DFO Precautionary Approach (PA) Framework. The probability that the stock is in the critical zone is 0.03.
- SSB decreased from 2012, but showed an increase in 2017. However, SSB is concentrated (75% of SSB) in ages 5 and 6, with few older (ages 7+) fish in the population.
- Recruitment has generally been at or above the time-series average since 2005, with particularly strong cohorts produced in 2006 and 2011.

- Estimated total mortality decreased slightly in 2016, but remains high. Over 2014-16, total mortality averaged 0.7 (50% survival per year), however the relative contributions of natural and fishing mortality to total mortality are unknown.
- Projection of the stock to 2020 was conducted assuming mortality rates will be within ± 20% of current values (2014 to 2016 average). Projected SSB shows a continuous decline to 2020 in most cases, with the decrease ranging from 23 to 58% (2017 to 2020). The risk of being below B_{lim} by 2019 ranges from 0.09 and 0.73, and by 2020 from 0.25 to 0.94.
- Ecosystem signals observed in 3Ps in recent years indicate that structural changes are occurring, and overall ecosystem productivity may be low. Although the full impacts of these changes on cod itself are not fully known, they imply that at least some aspects of cod productivity may be impaired.

OTHER CONSIDERATIONS

Management Considerations

The assessment of 3Ps cod is based on a cohort model that utilizes data from the DFO spring RV survey. Other data sources are typically examined during the course of the assessment meeting but have previously been eliminated as potential inputs for modeling population dynamics due to questions regarding reliability (e.g., catch), concerns related to limited spatial coverage (logbook data, sentinel data, tagging data), and/or the inability to incorporate more than one data source into the current model formulation. Given concerns regarding the current modeling approach, an initial technical meeting was held following the present assessment and participants agreed to work toward a full re-evaluation of all data sources over the next year. A second technical meeting is scheduled to occur following the October 2018 assessment of 3Ps cod. These activities are the first steps toward a framework meeting to evaluate modelling options, which is anticipated to have a time frame of two years.

A seasonal closure of the entire 3Ps stock area (typically March to mid-May) occurs annually and is intended to minimize fishing on spawning aggregations. Some harvesters have suggested that the time of spawning has been delayed in recent years and that the timing of the closure may no longer be appropriate. Fishing was permitted in March 2014 and 2015 to provide those harvesters with increased flexibility in accessing the resource. In 2015 and 2016, samples collected from the Halibut Channel area (Southern 3Ps) by industry (March) and from the DFO multispecies survey (April) indicated that spawning in this area began in April. No spawning was observed in March but egg sizes suggested that at least some fish were nearing spawning at the time of capture. The original recommendation for the 3Ps spawning closure came with the suggestion that spawning in this stock occurs during April-June but with the acknowledgement that "spawning ground behavior typically begins in March" (FRCC 2001). Hence, the recommended (and subsequently adopted) closure time of March 1-June 30 was presumably intended to protect not only spawning but also pre-spawning aggregations. If the objective of the 3Ps spawning closure is still to protect spawning and pre-spawning aggregations, then the starting date of the closure is likely still appropriate. It should be noted, however, that the current closure end date of mid-May almost certainly does not protect the full spawning period for this stock.

Catches of approximately half the TAC did not promote recovery of the stock toward the healthy zone; therefore, at the 2016 assessment, it was not considered prudent to provide advice based on the HCR.

SOURCES OF INFORMATION

This Science Advisory Report is from the October 17-18, 2017 Assessment of NAFO Subdivision 3Ps Atlantic Cod. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Cadigan, N. 2010. Trends in Northwest Atlantic Fisheries Organization (NAFO) Subdivision 3Ps Cod (*Gadus morhua*) stock size based on a separable total mortality model and the Fisheries and Oceans Canada Research Vessel survey index. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/015. iv + 43 p.

FRCC. 2001. Conservation requirements for groundfish stocks in sub-areas 0, 2 + 3. Ottawa, Canada. 39 p.

Méthot, R., M. Castonguay, Y. Lambert, C. Audet and S. Campana. 2005. Spatio-temporal Distribution of Spawning and Stock Mixing of Atlantic Cod from the Northern Gulf of St. Lawrence and Southern Newfoundland Stocks on Burgeo Bank as Revealed by Maturity and Trace Elements of Otoliths. J. Northw. Atl. Fish. Sci. 36: 1–12

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